Nano-Mechanical Characterization Tools for *In-Situ* Deformation and Morphology of Materials

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We are providing mechanical characterization tools for nano- and micro-mechanical experimental data in support of multiscale material modeling efforts.

Project Goals

Our goals are to produce a suite of nano- and micro-mechanical deformation test stages, with various load ranges that can be inserted into a scanning electron microscope (SEM), transmission electron microscope (TEM), atomic force microscope (AFM), and a desktop video system for extreme imaging and surface topography during precision controlled deformation. In addition to the deformation stages, we have a variety of new nano- and micro-tensile/fracture test specimens and grips.

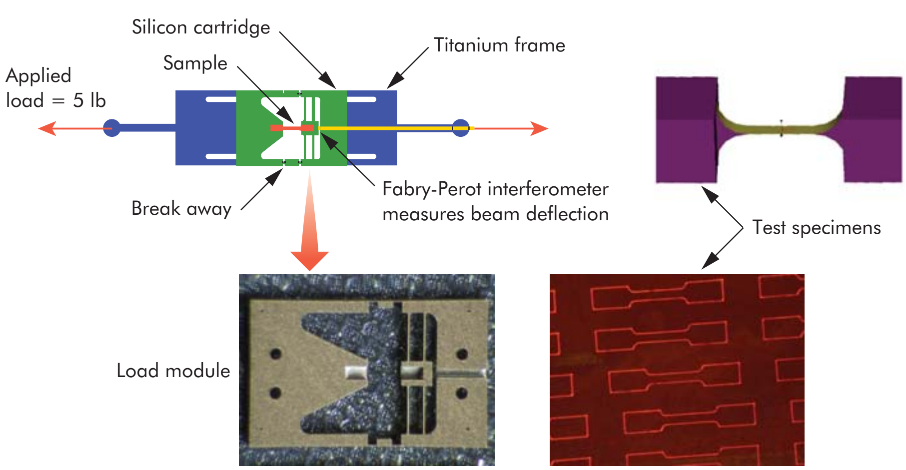

Figure 1. TEM loading stage and specimen. This system uses an external loading frame to deform the test specimen with loads up to 0.0005 lbs. The loading frames are fabricated at LLNL's Center for Microtechnology and Nanotechnology.

Relevance to LLNL Mission

These tools allow one to map out the local *in situ* morphology and inter-granular, inter-particulate, or inter-molecular deformation fields in materials that are subjected to local mechanical stresses. Nanoscale stress-strain data would be obtained which would allow the characterization of localized constitutive models. Load/deformation fields in the vicinity of crack tips in materials could be used to characterize and validate various localized fracture mechanics models. In addition, the small-scale deformation stages can be used to characterize the strength of micro- and nanoscale reinforcements, small samples of material where traditional large specimens cannot be obtained, and the adhesive bond strength of small joints and miniaturized components. The stages have also been reconfigured to study the mechanical properties of the NIF target capsules.

An accurate understanding of the relations between material morphology, deformation, and fracture will provide critical information for enhancing our ability to model the macroscopic response of all materials in general.

FY2004 Accomplishments and Results

Four deformation stages have been fabricated, with progressively higher full-scale load ranges from 0.0005 lbs, 10 lbs, 200 lbs, and 1000 lbs.

Our smallest stage allows deformation imaging using the TEM (Fig. 1). At this imaging level one will be able to see actual dislocation movements. The test specimen used in this extremely small device has a gage section that is 0.2 μm thick × 100 μm wide, which requires focused ion beam machining.

Figure 2 shows our SEM-compatible stages and current tensile specimen. This specimen has a gage section of 0.02 in. thick × 0.04 in. in width. Twenty of these specimens could be machined from a single dime. At this imaging level, one will be able to see inter-granular deformation fields.

Due to popular demand, a slightly larger test system was created to study material response as well as miniaturized components (Fig. 3). This system has a 1000-lb capacity and uses a video microscope (15 × to 1000 ×) for imaging.

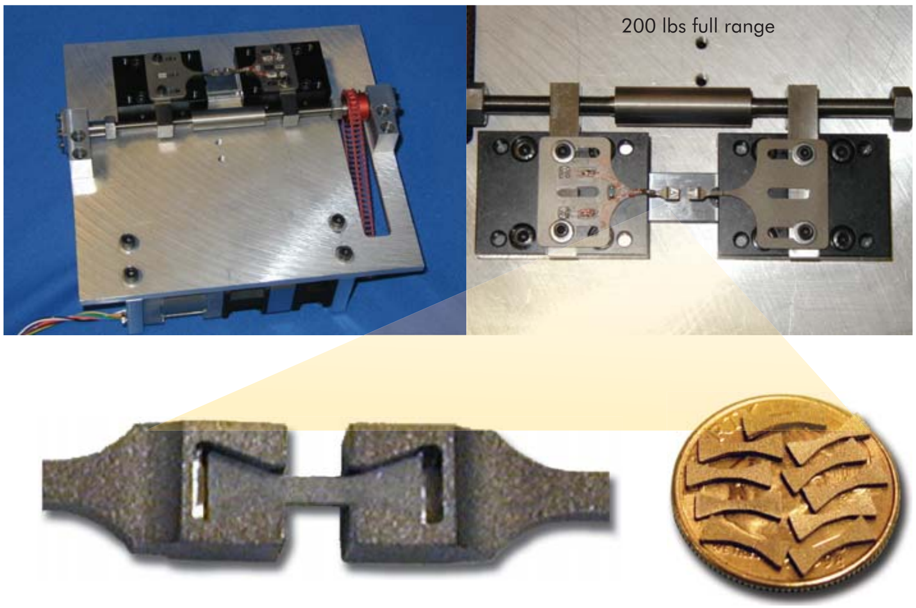

Figure 2. . SEM micro-stage with 1 in. of motion, .000002 in. resolution, and 200-lb force capacity. Test specimen is shown relative to a dime. Specimens are machined with wire EDM.

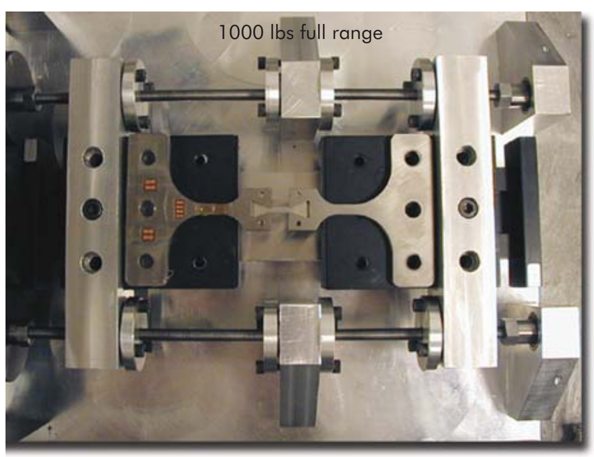

Figure 3. Desktop video micro-stage with 1000-lb force capacity, and tensile test specimen. Specimen is 1.0 in. long × 0.10 in. wide × 0.04 in. thick. Specimens are machined with wire EDM or standard milling practices.